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SOIL-VEGETATION CORRELATIONS IN THE SANDHILLS AND RAINWATER BASIN WETLANDS OF NEBRASKA



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SOIL-VEGETATION CORRELATIONS IN THE SANDHILLS
AND RAINWATER BASIN WETLANDS OF NEBRASKA

by

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PREFACE

The National Ecology Center of the U.S. Fish and Wildlife Service (FWS) is supporting a series of field research studies to document relationships between hydric soils and wetland vegetation in selected wetlands throughout the United States. This study is one of that series. It is a continuation of the FWS effort, begun by Wentworth and Johnson (1986), to develop a procedure using vegetation to designate wetlands based on the indicator status of wetland vegetation as described by the FWS "National List of Plants that Occur in Wetlands" (Reed 1986a). This list classifies vascular plants of the U.S. into one of five categories according to their natural frequency of occurrence in wetlands. Concurrent with the development of the wetland plant list, the Soil Conservation Service (SCS) developed the "National List of Hydric Soils" (SCS 1985a). Studies supported by the National Ecology Center quantitatively compare associations of plant species, designated according to their hydric nature using the Wentworth and Johnson (1986) procedure, with the hydric nature of soils according to their designation on the SCS hydric soils list. The studies are being conducted across moisture gradients at a variety of wetland sites throughout the U.S. Several studies have been modified to obtain information on groundwater hydrology.

These studies were conceived in 1984 and implemented in 1985 in response to internal planning efforts of the FWS. They parallel, to some extent, ongoing efforts by the SCS to delineate wetlands for Section 1221 of the Food Security Act of 1985 (the swampbuster provision). The SCS and FWS provided joint guidance and direction in the development of the Wentworth and Johnson (1986) procedure, and the SCS currently is testing a procedure that combines hydric soils and the Wentworth and Johnson procedure for practical wetland delineation. The efforts of both agencies are complimentary and are being conducted in close cooperation.

The primary objectives of these studies are to (1) assemble a quantitative data base of wetland plant community dominance and codominance for determining the relationship between wetland plants and hydric soils; (2) test various delineation algorithms based on the indicator status of plants against independent measures of hydric character, primarily hydric soils; and (3) test, in some instances, the correlation with groundwater hydrology. The results of these studies also can be used, with little or no supplementary hydrologic information, to compare wetland delineation methods of the Corps of Engineers (1987) and the Environmental Protection Agency (Sipple 1987).

Any questions or suggestions regarding these studies should be directed to: Charles Segelquist, 2627 Redwing Road, Creekside One Building, Fort Collins, Colorado, 80526-2899, phone FTS 323-5384 or Commercial (303) 226-9384.

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INTRODUCTION

Wetlands are defined by the U.S. Fish and Wildlife Service as lands that are

... transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.... Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.... The upland limit of a wetland is designated as: (1) the boundary between land with predominantly mesophytic and xerophytic cover; (2) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or (3) in the case of wetlands without vegetation or soil, the boundary between land that is flooded or saturated at some time each year and land that is not (Cowardin et al. 1979:3-4).

Wetland systems across the United States are threatened by human impacts. Agricultural conversions, urban encroachment, and other habitat modifications have decreased wetland acreage. Only 45% of the original wetland acreage in the United States remained in the mid-1970's (Tiner and Wilen 1983).

With past and continued losses of natural wetlands and increased socioeconomic interests in wetlands, the importance of remaining wetlands has increased. Wetland and deepwater ecosystems provide fish and wildlife habitats, flood control, water quality maintenance, ecosystem integrity, and socioeconomic benefits. The ability to delineate wetlands therefore becomes essential for agencies charged with their management and protection, such as the U.S. Fish and Wildlife Service.

The Cowardin et al. (1979) classification system defines wetland systems by vegetation, soils, and water regime within a given area. Hydrophytic vegetation is defined as plants that grow in water or a substrate that is at least periodically deficient in oxygen during a growing season as a result of excessive water content (Soil Conservation Service 1986a). Hydric soils are defined as soils that in an undrained condition are saturated, flooded, or inundated long enough during the growing season to develop anaerobic conditions, which favor the growth and regeneration of hydrophytic vegetation (Soil Conservation Service 1985a).

Correlations between vegetation and soil parameters provide essential guidelines for delineation and management of important wetland types throughout the United States. The U.S. Fish and Wildlife Service (Reed 1986a) has compiled a list of wetland plants (hydrophytes) and the Soil Conservation Service (1985a) has compiled a list of hydric soils to facilitate wetland delineation. Methodologies developed by Wentworth and Johnson (1986) for delineating wetlands solely by vegetation were used to determine whether hydric soils identified by the Soil Conservation Service in Nebraska (1985b) support predominantly wetland plants as identified by the U.S. Fish and Wildlife Service (Reed 1986a, 1986b).

The Rainwater Basin and Sandhills regions in Nebraska were selected for a wetland vegetation-hydric soil correlation study as part of a National study by the National Ecology Center of the U.S. Fish and Wildlife Service. The primary objectives of our study were (1) to assemble a quantitative data base for determining relationships between the U.S. Fish and Wildlife Service National Wetland Plant List (Reed 1986b) and the Soil Conservation Service (1985b) Hydric Soils List, (2) to estimate the extent to which hydric soils supported a prevalence of wetland vegetation as identified by the indicator status of plants recorded on the wetland plant list, and (3) to test Wentworth and Johnson (1986) and other wetland delineation methodologies as they pertain to soil-vegetation correlations.

DESCRIPTION OF STUDY AREAS

This study was performed at wetlands in the Rainwater Basin and Sandhills regions of Nebraska. Four areas were selected for the study: adjacent Clay and Fillmore counties in the eastern Rainwater Basin, Rock County in the northeast Sandhills region, Valentine National Wildlife Refuge in the north-central Sandhills region, and Crescent Lake National Wildlife Refuge in the southwest Sandhills region (Figure 1).

RAINWATER BASIN

The Rainwater Basin encompasses a drainage area in south-central Nebraska south of the Platte River that includes portions of 17 counties. The basin covers approximately 6,720 km² (Environmental Protection Agency 1986) and was formed from windblown silt deposits. Sink-like depressions occur throughout the terrain, and water accumulations have leached and concentrated clay particles in the subsoils, forming a 0.1-2 m clay layer impervious to water (U.S. Fish and Wildlife Service 1985a). Wetlands that are located in depressions rely heavily on surface runoff and natural rainfall for water; therefore, wetland dynamics within the Rainwater Basin are influenced greatly by hydrologic events.

Climate in Clay and Fillmore counties, Nebraska, is characterized by cold winters and hot summers. Mean total annual precipitation in Clay and Fillmore counties is 69.9 cm; heaviest rainfalls occur in late spring and early summer (Hammer et al. 1981, 1986). Precipitation was below normal in these counties during our field season (T. Hupf, U.S. Fish and Wildlife Service, Grand Island, NE; pers. comm.).

During presettlement times, the Rainwater Basin contained nearly 4,000 wetlands, covering an area of approximately 38,000 ha. By 1981, less than 10% of the original wetlands remained, due to agricultural conversions (Farrar 1982). Of the remaining wetlands, only 49% are under State or Federal protection (U.S. Fish and Wildlife Service 1985a). Wetlands of the Rainwater Basin provide spring staging areas for 5-7 million waterfowl/year in the Central Flyway (Environmental Protection Agency 1986); nearly all of the midcontinental population of 300,000 white-fronted geese (Anser albifrons) stage in the basin each year (U.S. Fish and Wildlife Service 1985a).

Six Federal Waterfowl Production Areas were chosen for our study in the Rainwater Basin. Although these areas are managed for waterfowl, sample sites with minimal vegetation modification were selected when possible (Table 1).

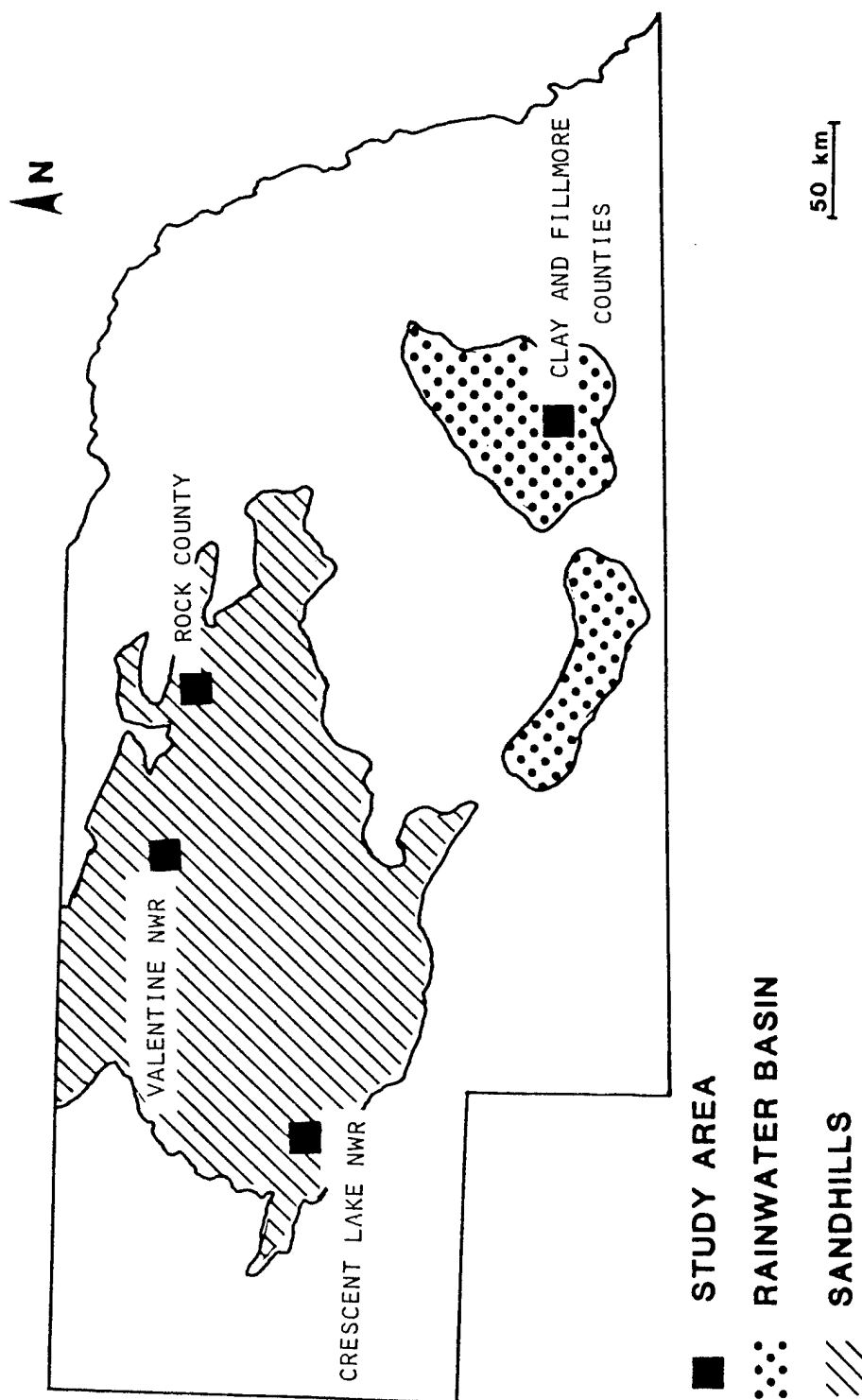


Figure 1. Rainwater Basin and Sandhills regions of Nebraska, with location of study areas.

THE SANDHILLS

The Sandhills region is the largest continuous sand dune formation in the western hemisphere, encompassing approximately 32,000 km². This region presumably was formed by wind action on late Tertiary and early Pleistocene deposits (McCarraher 1970). Soils of the Sandhills are highly erodible, and soil "blowouts" occur frequently where vegetative cover is insufficient. At the turn of the century, Rydberg (1895) documented blowouts 100 m in diameter and 15-20 m deep. Climate in the Sandhills is semiarid, with mean annual precipitation ranging from 63.5 cm in the east to 37.6 cm in the west (Rundquist 1983). Rock County receives 55.9 cm mean annual precipitation, with 75% occurring between April and September (Zink et al. 1985); precipitation in the county apparently was normal at the time of our study. Valentine National Wildlife Refuge was experiencing a wet spring at the time of our study, whereas conditions were drier than normal at Crescent Lake National Wildlife Refuge.

The Sandhills contain approximately 557,590 ha of wetlands (Rundquist et al. 1981). Over 11,340 ha of wetlands, or 15% of the original wetland acreage, were lost from the Sandhills region prior to the 1970's (Nebraska Game and Parks Commission 1972). Wetland acreage losses as of 1986 may be in excess of 30% for the entire Sandhills region, including estimated habitat losses of 92% in Loup County alone (D. Gersib, Nebraska Game and Parks Commission, Lincoln, NE; pers. comm.). Center-pivot irrigation, with associated ditching, levelling, filling of wetlands, and groundwater depletion, is the major cause of wetland habitat destruction in the Sandhills (T. Taylor, U.S. Fish and Wildlife Service, Grand Island, NE; pers. comm.); use of center-pivots in the Sandhills has increased 1,746% since 1972 (U.S. Fish and Wildlife Service 1981). The localized ground water table northwest of Alliance, Nebraska has been depleted 10 m since 1946 (Conservation and Survey Division 1986); a reduction of only 1 m can alter acreage and type of a Sandhill wetland (Soil Conservation Service 1986b).

Despite habitat losses, Sandhill wetlands provide nesting and migration sites for millions of waterfowl, songbirds, and shorebirds (Wolfe 1984), as well as habitats for fish and terrestrial wildlife (Rundquist 1983; U.S. Fish and Wildlife Service 1985b). The Sandhills were listed as one of 34 geographic areas of concern in the North American Waterfowl Management Plan adopted by the United States and Canada in 1985, and are considered by the Nebraska Game and Parks Commission to be the most important waterfowl production area in the State (D. Gersib, pers. comm.).

Wetlands in our study were located in three areas of the Sandhills (Figure 1): Rock County (263,600 ha); Valentine National Wildlife Refuge (28,960 ha), Cherry County; and Crescent Lake National Wildlife Refuge (18,630 ha), Garden County. Vegetation in the wetlands sampled was in an undisturbed condition, unless otherwise noted (Table 1). Vegetation associations often included introduced exotics, but were relatively free from grazing, crop production, and human impact. Modified wetlands were included in our study only when a soil series was not dispersed widely throughout the study area.

Table 1. Wetlands and soil series sampled, with land use practices.

Wetland	Date	Soil series	Land use ^a
RAINWATER BASIN			
McMurtrey WPA ^b	6/5/86	Massie, Scott, Butler	tilling
	6/6/86	Scott, Butler	in Butler
Massie WPA	6/6/86	Massie, Scott, Butler	
Hansen WPA	6/7/86	Massie, Fillmore, Scott, Butler	
Mallard Haven WPA	6/7/86	Massie, Fillmore, Scott, Butler	
Rolland WPA	6/7/86	Fillmore	cattle grazing
Lange WPA	6/7/86	Fillmore	
ROCK COUNTY			
Peterson Lake	6/13/86	Marlake, Tryon	
Linke Lake	6/14/86	Marlake, Loup	
Adams Lake	6/14/86	Loup	cattle grazing
Fish Lake	6/16/86	Marlake, Loup, Tryon	
South Twin Lake	6/18/86	Tryon	
Smith Lake	6/18/86	Marlake, Loup, Tryon	
VALENTINE NATIONAL WILDLIFE REFUGE			
Tom's Lake	6/26/86	Marlake, Tryon., Els	
"21" Lake	6/27/86	Marlake, Tryon, Ipage	
Center Lake	6/27/86	Marlake, Tryon, Els	
	7/2/86	Els	
Calf Camp Marsh	6/29/86	Marlake, Tryon	
	7/2/86	Els	
CRESCENT LAKE NATIONAL WILDLIFE REFUGE			
Martin Lake	7/8/86	Marlake, Els	
Section 30E Marsh	7/8/86	Marlake, Hoffland, Els	
Perrin Lake	7/8/86	Marlake, Hoffland, Els	drawdown
Goose Lake	7/9/86	Marlake, Hoffland, Loup, Valentine	
Island Lake	7/10/86	Marlake, Tryon	cattle
	7/11/86	Marlake, Els	grazing
Roundup Lake	7/11/86	Marlake, Tryon, Valentine	
Gimlet Lake	7/12/86	Marlake, Loup, Els	

^aRepresents known land use practices at the time of our study; unless otherwise designated, areas were in ungrazed vegetation.

^bWPA: Federal Waterfowl Production Area

Most wetlands in Rock County were located near pivot irrigation sites; depletion of ground water by pivot farming may have altered the original plant community, although effects of pivots on vegetation composition cannot be estimated from our study. Wetlands sampled at Valentine National Wildlife Refuge have been grazed and hayed in past years, but not at the time of our study. Several wetlands in Crescent Lake National Wildlife Refuge were equipped with water control structures (only one site was in drawdown condition at the time of our study), and Island Lake showed evidence of recent grazing (Table 1).

METHODS

Known hydric and nonhydric soils were identified from the Hydric Soils List of Nebraska (Soil Conservation Service 1985b). Ideally, all known hydric and at least one nonhydric soil series were sampled; descriptions of these series are given in Appendix A. At least four wetlands were chosen within each study area where selected soils were represented. Additional wetlands were selected if all soil series were not present in a given wetland, such that four replicates existed for each soil series sampled.

Field work was conducted from 5 June - 12 July 1986. Recent (post-1980) soil survey maps were available for Clay and Fillmore counties in the Rainwater Basin, Rock County, and Crescent Lake National Wildlife Refuge in Garden County. Soils in Valentine National Wildlife Refuge had not been mapped since the mid-1950's; Dave Hoover and Roger Hammer (Soil Survey Office, Valentine, NE) were contacted to ground-truth soils along established transects at selected wetlands.

Sampling sites were located randomly on soil survey maps (when available). Within a given soil series, vegetation in the study plots was separated into four strata: trees, tall shrubs, short shrubs, and ground cover layers (Table 2). Centers of 100 m² study plots were established randomly in a soil series at approximately 10-30 m intervals, so they did not overlap. Quadrats in each of 5-100 m² study plots/soil series vegetation strata were established randomly; paired ground cover plots were established by blindly tossing a 0.5 m² quadrat sampler. Qualitative field estimates of soil moisture content were recorded for each study plot (see legend of Appendix B for description).

Plant species were assigned ecological indices from the Wetland Plant List for the South Plains Region (Reed 1986b), based on frequencies of occurrence in wetlands (Table 3). Species not listed were assigned the most conservative, appropriate modifiers; for example, Bromus inermis was not listed, but we designated it as "facultative upland" because this was the most conservative modifier listed for the genus Bromus (Reed 1986a). Individuals that could not be identified to the species level due to advanced phenology were denoted by "spp." and were assigned the driest modifier listed for the genus; all individuals classified only to genus were analyzed together.

Weighted averages for each vegetation strata were calculated for each soil series and individual wetlands within a soil series in a study area. The equation used was adopted from Wentworth and Johnson (1986):

Table 2. Sampling schemes for vegetation strata.

Strata and definition	Variables measured	Size of quadrats	Replications per soil series
Trees: all stems ≥ 7.5 cm dbh	Density: dbh (cm) all stems	100 m ²	5
Tall Shrubs: woody species < 7.5 cm dbh, ≥ 1.3 m tall	Density: count all main leaders	4 m ²	5
Short Shrubs: woody species < 1.3 m, ≥ 0.5 m	Density: count all individual plants emerging from ground	4 m ²	5
Ground Cover: woody species < 0.5 m and all herbaceous species regardless of height	percent cover in 0-6 Daubenmire (1968) classes ^a	0.5 m ²	10

^aDaubenmire classes are listed in Table 4.

Table 3. Ecological indices used for weighted, presence/absence, and Michener averages, with definitions of modifiers in the Wetland Plant List, South Plains region.

Modifier	Ecological indices ^a			Definition
	W _j	P _j	M _j	
Obligate	1	1	1	species always occurring in wetlands (frequency > 99%)
Facultative wet and fac. wet drawdown ^b	2	2	.82	species usually occurring in wetlands (67%-99% frequency)
Facultative and fac. drawdown	3	3	.50	species sometimes occurring in wetlands (34%-66% frequency)
Facultative upland and fac. upland drawdown	4	4	.18	species seldom occurring in wetlands (1%-33% frequency)
Upland and upland drawdown	5	5	0	species occurring in wetlands with less than 1% frequency; also includes all species not assigned one of the above modifiers

^aW_j = weighted average (Wentworth and Johnson 1986)

P_j = presence/absence average

M_j = Michener average (Michener 1983)

^bDrawdown: indicates species favored by drawdown conditions.

$$W_j = \left(\sum_{i=1}^n I_{ij} E_i \right) / \left(\sum_{i=1}^n I_{ij} \right),$$

where W_j = weighted average for stand j , I_{ij} = importance value for species i in stand j , E_i = ecological index for species i , and n = number of species in stand j . Importance values corresponded to Daubenmire (1968) cover classes defined in Table 4. The ecological index for each species corresponded to modifiers recorded in the Wetland Plant List (Table 3).

Modified equations were used to calculate presence/absence averages (P_j), referred to as index averaging by Wentworth and Johnson (1986), and Michener (1983) averages (M_j) for each soil series and wetland within a soil series. To calculate P_j , the parameter I_{ij} was assigned a value of 1 when a species was present or 0 when absent. Weighted ecological indices used in Michener averages are listed in Table 3.

Range, mean, standard deviation, and standard error of mean values were calculated for ecological indices of vegetation based on weighted averages, presence/absence averages, and Michener averages by soil series and individual wetlands within each soil series. Averages for soil series were analyzed using Analysis of Variance and Duncan's multiple range tests. Identical analyses were used to make comparisons between weighted and presence/absence averages for soil series. Contrasts with Michener averages were not made because calculated values were not comparable. Ecological indices for vegetation based on weighted averages and presence/absence averages less than 3.00 (Wentworth and Johnson 1986) or Michener (1983) averages greater than 0.50 are considered indicators of wetland conditions.

Table 4. Importance values assigned to ground cover stratum (Daubenmire 1968).

Importance value	Definition
1	Percent ground cover of 0.1-5
2	Percent ground cover of 6-25
3	Percent ground cover of 26-50
4	Percent ground cover of 51-75
5	Percent ground cover of 76-95
6	Percent ground cover of 96-100

RESULTS

Of the 224 species identified in this study (Appendix B), 214 were sampled in the ground cover stratum: 64 from the Rainwater Basin and 194 from the Sandhills (Rock County, 92 species; Valentine National Wildlife Refuge, 89 species; Crescent Lake National Wildlife Refuge, 132 species). Tree and shrub strata composed very little of the vegetation; 4 tree species and 2 shrub species (Ulmus americana occurred in both strata) were associated with plots in the Rainwater Basin, compared to no trees and 5 shrub species in the Sandhills.

Only ground cover data were analyzed, because other vegetational strata were not represented sufficiently at the study areas. Means, standard errors of means, and ranges were calculated for weighted averages, presence/absence averages, and Michener averages for soil series and wetland sites in each study area (Tables 5, 6, and 7). Cover values for unknown species were not included in these quantitative analyses.

Duncan's multiple range tests were performed on ecological indices for weighted averages, presence/absence averages, and Michener averages for soil series (Tables 8, 9, and 10, respectively). Values in the same letter grouping are not statistically different. Vegetation is considered to be wetland or hydric when weighted averages and presence/absence averages are less than 3.00 or Michener averages are greater than 0.50; hydric soils as identified by the Soil Conservation Service (1985b) are indicated by asterisks (*). Duncan's multiple range tests for comparisons between weighted and presence/absence averages revealed that these values were not statistically different for any given soil series (Table 11). Because ecological indices were weighted differently in Michener averages (Table 3), they were not comparable statistically to the other averages. Frequencies of occurrence of species were determined for individual soil series within study areas (Appendix C).

Prevalence of hydrophytic vegetation determinations from weighted and presence/absence averages corresponded to the Hydric Soils List for all soil series except one. Discrepancies existed within the Tryon series, a hydric soil, among geographic locations. At Rock County and Valentine National Wildlife Refuge, both weighted and presence/absence averages indicated that Tryon supported a prevalence of hydrophytic vegetation, whereas the calculated value was greater than 3.00 at Crescent Lake National Wildlife Refuge, indicating that a prevalence of hydrophytic vegetation did not occur (Table 11). The Butler series, a suspected hydric soil not included in the SCS list, did not support a prevalence of wetland vegetation as indicated by either methods of calculation (Table 11).

Table 5. Means, standard errors of means, and ranges for weighted averages by soil series and wetlands.

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
RAINWATER BASIN				
*Massie	40	1.413	0.080	2.000
McMurtrey WPA	10	1.707	0.263	2.000
Massie WPA	10	1.129	0.086	0.667
Hansen WPA	10	1.303	0.073	0.667
Mallard Haven WPA	10	1.513	0.089	1.000
*Fillmore	40	2.445	0.082	1.905
Hansen WPA	10	2.834	0.077	0.800
Mallard Haven WPA	10	2.873	0.102	1.111
Rolland WPA	10	2.195	0.116	1.141
Lange WPA	10	1.878	0.092	0.871
*Scott	39	2.855	0.107	3.000
McMurtrey WPA	10	2.460	0.285	2.333
Massie WPA	10	2.984	0.181	1.700
Hansen WPA	10	3.218	0.176	1.455
Mallard Haven WPA	9	2.748	0.111	1.000
Butler	38	3.221	0.109	3.000
McMurtrey WPA	10	2.959	0.341	3.000
Massie WPA	10	3.283	0.091	0.800
Hansen WPA	8	3.013	0.123	1.107
Mallard Haven WPA	10	3.589	0.158	1.455
ROCK COUNTY				
*Marlake	40	1.280	0.050	1.100
Peterson Lake	10	1.437	0.130	1.100
Linke Lake	10	1.059	0.025	0.200
Fish Lake	10	1.445	0.091	0.923
Smith Lake	10	1.181	0.075	0.714

(Continued)

Table 5. (Continued).

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
*Loup	40	2.278	0.080	2.028
Linke Lake	10	2.667	0.093	0.917
Adams Lake	10	2.440	0.121	1.052
Fish Lake	10	2.085	0.205	1.878
Smith Lake	10	1.919	0.090	0.918
*Tryon	40	2.474	0.136	2.667
Peterson Lake	10	2.155	0.095	0.967
Fish Lake	10	1.589	0.087	0.917
South Twin Lake	10	3.795	0.067	0.571
Smith Lake	10	2.356	0.076	0.750
VALENTINE NATIONAL WILDLIFE REFUGE				
*Marlake	40	1.257	0.025	0.667
Tom's Lake	10	1.299	0.023	0.206
"21" Lake	10	1.290	0.035	0.357
Center Lake	10	1.232	0.066	0.667
Calf Camp Marsh	10	1.207	0.065	0.571
*Tryon	40	2.532	0.110	2.624
Tom's Lake	10	2.746	0.225	2.141
"21" Lake	10	2.674	0.181	1.762
Center Lake	10	2.701	0.223	2.346
Calf Camp Marsh	10	2.007	0.184	1.917
Els	30	3.235	0.080	1.800
Tom's Lake	10	3.583	0.094	1.077
Center Lake	10	2.869	0.092	0.875
Calf Camp Marsh	10	3.253	0.125	1.400
Ipage	10	3.339	0.103	1.011
"21" Lake	10	3.339	0.103	1.011

(Continued)

Table 5. (Concluded).

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
CRESCENT LAKE NATIONAL WILDLIFE REFUGE				
*Marlake	109	1.584	0.036	1.600
Martin Lake	10	1.198	0.061	0.571
Section 30E Marsh	10	1.496	0.096	1.000
Perrin Lake	10	1.750	0.171	1.500
Goose Lake	19	1.596	0.071	1.119
Island Lake	20	1.758	0.103	1.457
Roundup Lake	20	1.439	0.063	1.111
Gimlet Lake	20	1.700	0.048	0.889
*Hoffland	40	2.471	0.082	2.286
Section 30E Marsh	20	2.552	0.118	1.762
Perrin Lake	10	2.398	0.212	2.190
Goose Lake	10	2.382	0.095	0.985
*Loup	40	2.399	0.063	1.536
Goose Lake	20	2.467	0.088	1.432
Gimlet Lake	20	2.331	0.089	1.286
*Tryon	40	3.308	0.090	2.167
Island Lake	20	3.694	0.058	0.750
Roundup Lake	20	2.923	0.119	1.738
Els	70	3.827	0.070	3.000
Martin Lake	10	3.594	0.171	1.433
Section 30E Marsh	10	3.990	0.091	0.889
Perrin Lake	10	2.854	0.179	1.667
Island Lake	20	4.148	0.097	2.000
Gimlet Lake	20	4.025	0.051	1.000
Valentine	40	4.263	0.053	1.250
Goose Lake	20	4.087	0.043	0.850
Roundup Lake	20	4.443	0.080	1.200

^aAsterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985b).

Table 6. Means, standard errors of means, and ranges for presence/absence averages by soil series and wetlands.

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
RAINWATER BASIN				
*Massie	40	1.427	0.079	1.800
McMurtrey WPA	10	1.691	0.239	1.800
Massie WPA	10	1.203	0.138	1.200
Hansen WPA	10	1.358	0.104	1.000
Mallard Haven WPA	10	1.453	0.081	1.000
*Fillmore	40	2.466	0.080	1.867
Hansen WPA	10	2.830	0.080	0.771
Mallard Haven WPA	10	2.845	0.097	0.950
Rolland WPA	10	2.312	0.094	0.917
Lange WPA	10	1.877	0.114	1.067
*Scott	39	2.836	0.106	3.000
McMurtrey WPA	10	2.308	0.257	2.333
Massie WPA	10	3.030	0.134	1.225
Hansen WPA	10	3.197	0.191	1.714
Mallard Haven WPA	9	2.805	0.130	1.250
Butler	38	3.229	0.108	3.000
McMurtrey WPA	10	2.889	0.335	3.000
Massie WPA	10	3.334	0.119	1.000
Hansen WPA	8	3.059	0.109	0.944
Mallard Haven WPA	10	3.599	0.132	1.167
ROCK COUNTY				
*Marlake	40	1.309	0.060	1.600
Peterson Lake	10	1.518	0.176	1.600
Linke Lake	10	1.088	0.040	0.333
Fish Lake	10	1.465	0.087	0.750
Smith Lake	10	1.167	0.079	0.800

(Continued)

Table 6. (Continued).

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
*Loup	40	2.354	0.084	2.175
Linke Lake	10	2.733	0.101	1.089
Adams Lake	10	2.593	0.094	1.107
Fish Lake	10	2.120	0.119	1.943
Smith Lake	10	1.970	0.136	1.125
*Tryon	40	2.491	0.132	2.750
Peterson Lake	10	2.144	0.081	0.944
Fish Lake	10	1.594	0.099	1.000
South Twin Lake	10	3.738	0.087	0.727
Smith Lake	10	2.489	0.066	0.689
VALENTINE NATIONAL WILDLIFE REFUGE				
*Marlake	40	1.264	0.025	0.600
Tom's Lake	10	1.330	0.028	0.250
"21" Lake	10	1.240	0.026	0.167
Center Lake	10	1.233	0.051	0.500
Calf Camp Marsh	10	1.254	0.076	0.600
*Tryon	40	2.516	0.100	2.657
Tom's Lake	10	2.689	0.210	2.094
"21" Lake	10	2.608	0.152	1.472
Center Lake	10	2.742	0.197	2.190
Calf Camp Marsh	10	2.023	0.169	1.625
Els	30	3.158	0.076	1.571
Tom's Lake	10	3.499	0.113	1.182
Center Lake	10	2.819	0.082	0.756
Calf Camp Marsh	10	3.156	0.101	1.000
Ipage	10	3.290	0.082	0.792
"21" Lake	10	3.290	0.082	0.792

(Continued)

Table 6. (Concluded).

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
CRESCENT LAKE NATIONAL WILDLIFE REFUGE				
*Marlake	109	1.662	0.042	2.000
Martin Lake	10	1.293	0.060	0.600
Section 30E Marsh	10	1.525	0.099	1.000
Perrin Lake	10	2.100	0.245	2.000
Goose Lake	19	1.599	0.072	1.133
Island Lake	20	1.843	0.110	1.400
Roundup Lake	20	1.476	0.067	1.333
Gimlet Lake	20	1.762	0.046	0.857
*Hoffland	40	2.490	0.084	2.250
Section 30E Marsh	20	2.601	0.129	2.000
Perrin Lake	10	2.368	0.187	2.250
Goose Lake	10	2.389	0.108	1.056
*Loup	40	2.411	0.062	1.286
Goose Lake	20	2.433	0.079	1.125
Gimlet Lake	20	2.388	0.096	1.286
*Tryon	40	3.306	0.087	2.250
Island Lake	20	3.643	0.066	0.857
Roundup Lake	20	2.968	0.122	2.000
Els	70	3.808	0.074	3.000
Martin Lake	10	3.450	0.196	1.650
Section 30E Marsh	10	3.962	0.109	0.917
Perrin Lake	10	2.795	0.172	1.750
Island Lake	20	4.214	0.082	1.500
Gimlet Lake	20	4.013	0.044	0.832
Valentine	40	4.207	0.055	1.286
Goose Lake	20	4.086	0.043	0.786
Roundup Lake	20	4.328	0.094	1.250

^aAsterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985b).

Table 7. Means, standard errors of means, and ranges for Michener averages by soil series and wetlands.

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
RAINWATER BASIN				
*Massie	40	0.907	0.020	0.523
McMurtrey WPA	10	0.818	0.068	0.523
Massie WPA	10	0.965	0.023	0.182
Hansen WPA	10	0.936	0.018	0.167
Mallard Haven WPA	10	0.908	0.016	0.180
*Fillmore	40	0.639	0.023	0.504
Hansen WPA	10	0.525	0.020	0.187
Mallard Haven WPA	10	0.533	0.031	0.324
Rolland WPA	10	0.699	0.033	0.328
Lange WPA	10	0.797	0.028	0.243
*Scott	39	0.522	0.030	0.820
McMurtrey WPA	10	0.629	0.075	0.607
Massie WPA	10	0.475	0.049	0.464
Hansen WPA	10	0.418	0.052	0.427
Mallard Haven WPA	9	0.571	0.033	0.299
Butler	38	0.415	0.030	0.820
McMurtrey WPA	10	0.483	0.092	0.820
Massie WPA	10	0.399	0.025	0.228
Hansen WPA	8	0.489	0.034	0.302
Mallard Haven WPA	10	0.302	0.046	0.427
ROCK COUNTY				
*Marlake	40	0.933	0.013	0.296
Peterson Lake	10	0.897	0.033	0.296
Linke Lake	10	0.989	0.005	0.036
Fish Lake	10	0.884	0.025	0.252
Smith Lake	10	0.963	0.017	0.169

(Continued)

Table 7. (Continued).

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
*Loup	40	0.677	0.022	0.546
Linke Lake	10	0.583	0.026	0.258
Adams Lake	10	0.628	0.035	0.313
Fish Lake	10	0.724	0.056	0.520
Smith Lake	10	0.771	0.025	0.254
*Tryon	40	0.624	0.039	0.760
Peterson Lake	10	0.722	0.026	0.256
Fish Lake	10	0.877	0.027	0.270
South Twin Lake	10	0.242	0.020	0.163
Smith Lake	10	0.656	0.019	0.181
VALENTINE NATIONAL WILDLIFE REFUGE				
*Marlake	40	0.951	0.005	0.133
Tom's Lake	10	0.946	0.004	0.037
"21" Lake	10	0.948	0.006	0.064
Center Lake	10	0.956	0.012	0.120
Calf Camp Marsh	10	0.954	0.015	0.133
*Tryon	10	0.608	0.031	0.731
Tom's Lake	10	0.545	0.063	0.589
"21" Lake	10	0.567	0.050	0.487
Center Lake	10	0.558	0.062	0.646
Calf Camp Marsh	10	0.761	0.051	0.532
Els	30	0.407	0.022	0.517
Tom's Lake	10	0.317	0.024	0.281
Center Lake	10	0.503	0.026	0.251
Calf Camp Marsh	10	0.402	0.039	0.434
Ipage	10	0.376	0.028	0.271
"21" Lake	10	0.376	0.028	0.271

(Continued)

Table 7. (Concluded).

Soil series/ ^a Wetland	n	Mean	Standard error of means	Range
CRESCENT LAKE NATIONAL WILDLIFE REFUGE				
*Marlake	109	0.874	0.009	0.410
Martin Lake	10	0.962	0.012	0.123
Section 30E Marsh	10	0.911	0.017	0.180
Perrin Lake	10	0.795	0.047	0.410
Goose Lake	19	0.887	0.015	0.241
Island Lake	20	0.825	0.026	0.374
Roundup Lake	20	0.918	0.013	0.262
Gimlet Lake	20	0.845	0.011	0.216
*Loup	40	0.666	0.019	0.431
Goose Lake	20	0.652	0.026	0.420
Gimlet Lake	20	0.680	0.027	0.365
*Hoffland	40	0.644	0.024	0.671
Section 30E Marsh	20	0.638	0.035	0.504
Perrin Lake	10	0.645	0.061	0.654
Goose Lake	10	0.656	0.026	0.281
*Tryon	40	0.402	0.028	0.670
Island Lake	20	0.277	0.018	0.240
Roundup Lake	20	0.526	0.036	0.533
Els	70	0.251	0.020	0.820
Martin Lake	10	0.308	0.047	0.370
Section 30E Marsh	10	0.198	0.023	0.222
Perrin Lake	10	0.542	0.058	0.533
Island Lake	20	0.173	0.023	0.472
Gimlet Lake	20	0.182	0.012	0.227
Valentine	40	0.145	0.011	0.272
Goose Lake	20	0.168	0.009	0.188
Roundup Lake	20	0.123	0.018	0.272

^aAsterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985b).

Table 8. Duncan's multiple range tests for weighted averages calculated for soil series.

Grouping ^a	Soil series ^b	Mean	n ^c
RAINWATER BASIN			
A	Butler	3.221	38
B	*Scott	2.855	39
C	*Fillmore	2.445	40
D	*Massie	1.413	40
ROCK COUNTY			
A	*Tryon	2.474	40
A	*Loup	2.278	40
B	*Marlake	1.280	40
VALENTINE NATIONAL WILDLIFE REFUGE			
A	Ipage	3.339	10
A	Els	3.235	30
B	*Tryon	2.532	40
C	*Marlake	1.257	40
CRESCENT LAKE NATIONAL WILDLIFE REFUGE			
A	Valentine	4.265	40
B	Els	3.827	70
C	*Tryon	3.308	40
D	*Loup	2.471	40
D	*Hoffland	2.399	40
E	*Marlake	1.584	109

(Continued)

Table 8. (Concluded).

^aMean values for soil series with the same letter grouping are not statistically different at 0.05 level.

^bAsterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985b).

^cIdeally, 40 observations were made within each hydric and nonhydric soil series. However, some deviations existed in our data set. In the Rainwater Basin, two observations are missing from the Butler series due to an error in data collection; one quadrat in the Scott series consisted of all unknown species, and thus was not incorporated into our analyses. No nonhydric soils were sampled in Rock County due to our oversight. Two nonhydric series were combined at Valentine National Wildlife Refuge (30 observations in the Els and 10 in the Ipage series) because of soil identification problems (see Methods section). Additional observations in the Marlake and Els series at Crescent Lake National Wildlife Refuge were made in conjunction with the Hoffland series to compare alkaline wetlands (containing Hoffland soils) and freshwater wetlands at a later date.

Table 9. Duncan's multiple range tests for presence/absence averages calculated for soil series.

Grouping ^a	Soil series ^b	Mean	n
RAINWATER BASIN			
A	Butler	3.229	38
B	*Scott	2.836	39
C	*Fillmore	2.466	40
D	*Massie	1.427	40
ROCK COUNTY			
A	*Tryon	2.491	40
A	*Loup	2.354	40
B	*Marlake	1.309	40
VALENTINE NATIONAL WILDLIFE REFUGE			
A	Ipage	3.290	10
A	Els	3.158	30
B	*Tryon	2.516	40
C	*Marlake	1.264	40
CRESCENT LAKE NATIONAL WILDLIFE REFUGE			
A	Valentine	4.207	40
B	Els	3.808	70
C	*Tryon	3.306	40
D	*Loup	2.490	40
D	*Hoffland	2.411	40
E	*Marlake	1.662	109

(Continued)

Table 9. (Concluded)

^aMean values for soil series with the same letter grouping are not statistically different.

^bAsterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985b).

Table 10. Duncan's multiple range tests for Michener averages calculated for soil series.

Grouping ^a	Soil series ^b	Mean	n
RAINWATER BASIN			
A	*Massie	0.907	40
B	*Fillmore	0.639	40
C	*Scott	0.522	39
D	Butler	0.415	38
ROCK COUNTY			
A	*Marlake	0.933	40
B	*Loup	0.677	40
B	*Tryon	0.624	40
VALENTINE NATIONAL WILDLIFE REFUGE			
A	*Marlake	0.951	40
B	*Tryon	0.608	40
C	Els	0.407	30
C	Ipage	0.376	10
CRESCENT LAKE NATIONAL WILDLIFE REFUGE			
A	*Marlake	0.874	109
B	*Loup	0.666	40
B	*Hoffland	0.644	40
C	*Tryon	0.402	40
D	Els	0.251	70
E	Valentine	0.145	40

(Continued)

Table 10. (Concluded).

^aMean values for soil series with the same letter grouping are not statistically different.

^bAsterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985b).

Table 11. Duncan's multiple range tests for comparisons among weighted averages and presence/absence averages calculated for soil series.

Soil series ^a	Grouping ^b	Weighted average	Presence/absence average	n
RAINWATER BASIN				
BUTLER	A	3.221	3.229	38
*SCOTT	B	2.855	2.836	39
*FILLMORE	C	2.445	2.466	40
*MASSIE	D	1.413	1.427	40
ROCK COUNTY				
*TRYON	A	2.474	2.491	40
*LOUP	A	2.278	2.354	40
*MARLAKE	B	1.280	1.309	40
VALENTINE NATIONAL WILDLIFE REFUGE				
IPAGE	A	3.339	3.290	10
ELS	A	3.235	3.158	30
*TRYON	B	2.532	2.516	40
*MARLAKE	C	1.257	1.264	40
CRESCENT LAKE NATIONAL WILDLIFE REFUGE				
VALENTINE	A	4.265	4.207	40
ELS	B	3.827	3.808	70
*TRYON	C	3.308	3.306	40
*HOF FLAND	D	2.471	2.490	40
*LOUP	D	2.399	2.411	40
*MARLAKE	E	1.584	1.662	109

(Continued)

Table 11. (Concluded).

^aAsterisks (*) indicate the soil series is included in the Hydric Soils List (Soil Conservation Service 1985b).

^b Mean values for soil series with the same letter grouping are not statistically significant.

Designations by Michener average corresponded well with those for weighted and presence/absence averages; indices greater than 0.50 indicated that a soil series contained a prevalence of hydrophytic vegetation (Table 10). As with weighted and presence/absence averages, Michener calculations did not indicate that the Tryon series at Crescent Lake National Wildlife Refuge supported primarily hydrophytic vegetation (Table 11).

DISCUSSION

Little information is available regarding Nebraska wetlands, and no known publications focus on vegetation-soil correlations in the State. An early survey of Sandhill vegetation by Rydberg (1895) categorized wetland vegetation into wet-valley and aquatic flora categories. Remote sensing of wetland vegetation communities was used to delineate selected Sandhill wetlands in Cherry County (Gilbert 1980; Gilbert et al. 1980). Currier (1981) identified 22 vegetation communities from the Platte River floodplain, Nebraska. The U.S. Army Corps of Engineers (1983) used vegetational zones (xeric, mesic, or hydric) to delineate wetlands in Garfield and Wheeler counties in the Sandhills. Rundquist (1983) used remote sensing to quantify historic changes in Sandhill wetland acreage by the Shaw and Fredine (1956) classification. The Rainwater Basin is the site of an ongoing cooperative research project conducted by the U.S. Army Corps of Engineers, Environmental Protection Agency, Nebraska Game and Parks Commission, and U.S. Fish and Wildlife Service; wetland types within the basin are being evaluated using vegetation and soil parameters.

Advantages and disadvantages existed for all averaging methods used in our study to correlate vegetation and soil parameters. Weighted and Michener averages used ocular estimates of percent cover, which could have increased experimental error; however, consistency was achieved by having these estimates made by the same researcher. Michener averages, using weighted ecological indices, adequately indicated a prevalence of hydrophytic vegetation on SCS hydric soils, and would be a suitable method for delineating wetland systems using vegetation and soil parameters. Proper identification of species and correct classification by ecological indices are critical for accurate weighted and presence/absence average calculations (Wentworth and Johnson 1986).

Comparisons between weighted and presence/absence averages indicated no statistical differences among calculated values for soil series. Excellent agreement between these two methods was noted in Wentworth and Johnson's (1986) analyses of Currier's (1981) vegetation community data. Percent cover as a measure of dominance for a species in a given soil series was incorporated into weighted averages but not in presence/absence average calculations. Species dominance apparently did not influence whether or not the averages correlated with hydric soils. Rather, ecological indices, which reflected frequency of occurrence in wetlands, provided sufficient information to determine a prevalence of hydrophytic vegetation for a given soil.

Although exclusive use of presence/absence averages could prove adequate in assessing wetlands, these calculations may represent too simplistic an

approach for complex wetlands. It has not been ascertained whether these calculations would produce similar results for separation of soils within other vegetation strata, because trees and shrubs were not present in testable quantities in the Rainwater Basin and Sandhills of Nebraska. Similar methods have been used to distinguish among vegetation communities, including ground cover, shrub, and tree strata (Wentworth and Johnson 1986). Therefore, presence/absence averaging probably would distinguish between hydric and nonhydric soils within shrub and tree strata.

Hydrological parameters were not incorporated into our analyses; however, moisture variances among study sites in soil series may have influenced our results. Weighted, presence/absence, and Michener average calculations for the Tryon series, a known hydric soil, indicated the series to be hydric in Rock County and Valentine National Wildlife Refuge, whereas the series was designated nonhydric at Crescent Lake National Wildlife Refuge. Two factors might account for this discrepancy. First, annual precipitation at Crescent Lake National Wildlife Refuge reportedly was below normal, which may have influenced species composition within study plots. Second, values calculated for Tryon series fell into the hydric category at Roundup Lake but not at Island Lake; the latter showed evidence of recent grazing in the Tryon series. Grazing at Island Lake may have altered plant species composition, thus affecting our calculations. Modified wetlands generally were not incorporated into our study, but because the Tryon series was abundant only in two wetlands in the refuge, the impacted area was included in our study.

Although the Butler series in the Rainwater Basin was not included in the Hydric Soils List, it has been considered a hydric soil by some biologists of the U.S. Fish and Wildlife Service. The Butler series, located above the Scott series in the landscape, was somewhat drier than the Scott; however, both series supported similar plant species. Scott (included in the list) and Butler soil plots most often were dominated by hydrophytes, such as Panicum virgatum (facultative) and Polygonum amphibium (obligate), in addition to more upland species; for example, Poa nemoralis, Ambrosia artemisiifolia, and Bromus inermis. Isolated outcroppings of Butler soils reportedly are more prone to agricultural modification, which discourages development of hydrophytic communities. Yet, when the Butler series is found in conjunction with other hydric series, such as Massie, Fillmore, and Scott, it supports a prevalence of hydrophytic vegetation (T. Taylor, pers. comm.).

In conclusion, our study was performed within known soil series, and areas where the identity of a soil series was not clearly defined were avoided. The application of these methodologies to delineate wetlands based on soil and vegetation should consider the constraints and limitations discussed herein.

CONCLUSIONS

Generally, prevalence indices of ground cover vegetation (i. e., weighted, presence/absence, and Michener averages) correlated with hydric/nonhydric soil series designations of the Soil Conservation Service. Degree of correlation among calculated values and known hydric soils from the Hydric Soils List determined the adequacy of the methods. Use of weighted ecological indices in Michener averages corresponded well to prevalence of hydrophytic vegetation in hydric soil series, and would be adequate for wetland delineation. However, weighted averages or presence/absence averages also gave good results, and would be suitable for delineating wetlands based on vegetation-soil relationships.

Weighted and presence/absence averages within soil series were not statistically different using Duncan's multiple range tests. Presence/absence average calculations do not require information regarding species dominance, and thus may be preferred. However, correct identification of all species within the area of question then becomes critical to generate accurate values for the presence/absence method, because all species are weighted equally within the soil series. Furthermore, analyses were not performed for shrub and tree strata because of insufficient abundance in the Rainwater Basin and Sandhills regions. It is inconclusive whether weighted and presence/absence averages would be comparable for these strata.

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APPENDIX A

DESCRIPTIONS OF SOIL SERIES

BUTLER: occurs above Scott and Fillmore series in the landscape; deep, nearly level, with a slope of 0-1%; somewhat poorly drained soils formed in loess or mixed loess and alluvium on uplands and high stream terraces; surface layer is dark grey silt loam 25 cm thick; subsurface layer is grey silt loam 5 cm thick, subsoil layer is very dark grey, very firm silty clay in upper 51 cm and dark grey, firm silty clay in lower 15 cm; substratum is grey silt loam; organic matter content is moderate and natural fertility is medium; mean annual precipitation range is 56-76 cm and mean annual temperature range is 9-13 °C; permeability is slow; most areas of this soil are farmed through irrigation or dryfarming; other areas exist as native grass, usually adjacent to wetlands; southcentral Nebraska and northcentral Kansas distribution.

ELS: occurs above Loup and Tryon and below Ipage series in the landscape; deep, poorly drained soil, with 0-3% slope; formed in aeolian and alluvial sands on depressed areas and valleys of the Sandhills and on foot slopes and stream terraces draining the Sandhills; surface layer is greyish brown fine sand 18 cm thick; subsoils layer is light brownish grey fine sand 18 cm thick; substratum is light grey mottled fine sand; mean annual precipitation range is 36-69 cm and mean annual temperature range is 8-11 °C; runoff is slow and permeability is rapid; most of the acreage is used for hayland or range; native vegetation is grassland; some acreage used for alfalfa, corn, grain sorghum, wheat, and introduced grasses; Nebraska Sandhills, Kansas, South Dakota, and Colorado distribution.

FILLMORE: occurs above Massie and below Butler series in the landscape; deep nearly level, with a slope of 0-1%; poorly drained claypan soil formed in loess in shallow depressions or basins of uplands and stream terraces; surface layer is grey silt loam 23 cm thick; subsurface layer is light grey silt loam 10 cm thick; subsoil layer is dark greyish brown, very firm clay in upper 19 in and greyish brown silty clay loam in lower 30 cm; substratum is pale brown silt loam; organic matter content is moderate and natural fertility is medium; mean annual precipitation range is 51-89 cm and mean annual temperature range is 10-13 °C; runoff is very slow or ponded and permeability of water and air is very slow in the claypan subsoil; about half the areas of this soil are farmed, and are primarily dryfarmed; the rest is in native grasses used for grazing, haying, and as wildlife habitat; southcentral and eastern Nebraska, and possibly northern Kansas distribution.

HOFFLAND: occurs above Marlake and below Els series in the landscape; deep, poorly drained soils, with 0-2% slope; formed in alluvial sediments in Sandhill valleys; high calcium carbonate content; surface soil is grey and light brownish grey fine sandy loam 28 cm thick; substratum is 76 cm light brownish grey fine sand over 20 cm dark greyish brown fine sandy loam over light grey fine sand; mean annual precipitation range is 38-46 cm and mean annual temperature range is 7-9 °C; runoff is slow or ponded, and permeability is rapid; nearly all acreage is in native grass and used for hayland and range; in the western Nebraska Sandhills distribution.

IPAGE: occurs above Els, Loup, and Tryon and below Valentine series in the landscape; deep, moderately well drained, with 0-6% slope; formed in aeolian and alluvial sands on upland valleys and along stream terraces; surface layer is dark greyish brown sand 13 cm thick; subsoil layer is greyish brown sand 15 cm thick; substratum is pale brown sand and very pale brown and white sand over light grey coarse sand 109 cm thick; mean annual precipitation range is 41-61 cm and mean annual temperature range is 8-11 °C; runoff is slow and permeability is rapid; principally used as hayland and range, but a small acreage is cultivated to corn and alfalfa; most of the acreage in corn is irrigated; native vegetation is grassland; Nebraska Sandhills and South Dakota distribution.

LOUP: occurs above Marlake and below Els series in the landscape; deep, nearly level, with a 0-2% slope; poorly drained soil formed in loamy and sandy alluvium bottomlands and around marshes and lakes; presence of mollic epipedon; surface layer is calcareous, very dark grey, and dark grey fine sandy loam 25 cm thick; subsurface layer is grey fine sand 10 cm thick; substratum is 109 cm of light grey and greyish brown fine sand over dark grey fine sandy loam; organic matter content is high; mean annual precipitation range is 38-66 cm and mean annual temperature range is 7-12 °C; permeability is rapid; depth to the water table ranges from 15-30 cm; soil is in native grass and is used for rangeland or hayland, but usually is too wet for farming; Nebraska Sandhills, South Dakota, and Colorado distribution.

MARLAKE: occurs below Hoffland, Loup, Tryon, Els, and Valentine series in the landscape; deep, nearly level, with 0-1% slope; poorly drained soil formed in colluvial and alluvial sands; located in depressions or basins on valley floors and in low areas bordering lakes and streams; surface layer is dark grey loamy fine sand 18 cm thick; subsoil is greyish brown loamy sand with thin strata of sandy loam and sand 23 cm thick; substratum is light grey mottled fine sand; organic matter content is high; mean annual precipitation range is 43-58 cm and mean annual temperature range is 8-11 °C; usually inundated during the growing season; permeability is high; soil used mostly as wildlife habitat; some areas are mowed in dry years for mulching materials; north-central, central, and western Nebraska distribution.

MASSIE: occurs below Scott and Fillmore series in the landscape; deep, nearly level, with 0-1% slope; very poorly drained claypan soil formed in loess modified by water in the lowest, wettest depressions or basins of uplands; typically there is a layer of partially decayed leaves and stems on the surface; surface layer is very dark grey, grey, or light grey silty clay loam 23 cm thick; subsoil layer is dark grey silty clay and silty clay loam in the upper 41 cm and grey and dark greyish brown clay and silty clay in the lower 127 cm; substratum is greyish brown silty clay loam; organic matter content is high and natural fertility is medium; mean annual precipitation range is 51-66 cm and mean annual temperature range is 10-12 °C; usually inundated to 15 cm during the growing season; permeability is very low in the claypan subsoil; the soil is in wetland vegetation and is used mainly by wildlife; it is unsuited to dryland farming or irrigation,

rangeland, and windbreaks; south-central and southeastern Nebraska distribution.

SCOTT: occurs above Massie and below Butler series in the landscape; deep, nearly level, with a 0-1% slope; very poorly drained claypan soil formed in loess or loess modified by water in the lower parts of depressions or basins of uplands; surface layer is very dark grey silt loam 13 cm thick; subsurface layer is grey silt loam 8 cm thick; subsoil layer is very dark grey mottled very firm silty clay and clay in upper 66 cm and dark greyish brown silty clay loam in lower 30 cm; substratum is brown silt loam; organic matter content is moderate, and natural fertility is medium; mean annual precipitation range is 41-71 cm and mean annual temperature range is 10-13 °C; soils are ponded for long durations and permeability is very slow in the claypan subsoil; nearly all areas of this soil are in wetland vegetation and native grasses; areas are used as wildlife habitat and for grazing and haying; other areas are farmed, but are unsuitable for irrigation; western and central Nebraska and adjoining areas of Kansas and northeast Colorado distribution.

TRYON: occurs above Marlake and below Els series in the landscape; deep, nearly level, with a 0-2% slope; formed in aeolian and alluvial sediments in Sandhill valley floors and on bottomlands of some major streams which drain the Sandhills; lacks mollic epipedon; surface layer is very dark brown loamy fine sand 13 cm thick; subsurface layer is light brownish grey loamy sand to grey fine sand 14-23 cm thick; substratum is 104 cm of light brownish grey fine sand over 18 cm of black fine sandy loam over dark grey fine sand; organic matter content is high; mean annual precipitation range is 36-61 cm and mean annual temperature range is 8-11 °C; permeability is rapid; soil is suited to grazing or haying, but is too wet for cultivation; Nebraska Sandhills and central Great Plains distribution.

VALENTINE: occurs above Els, Loup, and Tryon series in the landscape; deep, excessively drained, with 0-6% slope; formed in aeolian sands; surface soil is dark greyish brown loamy fine sand 38 cm thick; subsoil is 64 cm of pale brown fine sand over clay and shaley clay; mean annual precipitation range is 41-64 cm and mean annual temperature range is 8-15 °C; runoff is slow due to rapid infiltration and permeability is rapid; capability to hold water is low; soils are dominated by native grass and are used for grazing and haying; some areas have been cultivated, but unless irrigated have returned to grass; north-central Nebraska, South Dakota, and Kansas distribution.

APPENDIX B

ALPHABETICAL LISTING OF SCIENTIFIC NAMES, CODES, AND NATIONAL WETLAND
INVENTORY ECOLOGICAL INDICES OF PLANT SPECIES IDENTIFIED IN THE
SANDHILLS AND RAINWATER BASIN WETLANDS OF NEBRASKA

LEGEND

SCIENTIFIC NAME: Scientific name for species.

CODE: Four to six character code assigned to species in the National Wetland Plant Inventory List (Reed 1986a).

E: Ecological index for species: ob = obligate, fw = facultative wetland, wd = facultative wetland favored by drawdown, fa = facultative, fd = facultative favored by drawdown, fu = facultative upland, ud = facultative upland favored by drawdown, up = upland, nc = not classified in the National Wetland Plant Inventory List; (see Table 3).

SCIENTIFIC NAME	CODE	E
Acer negundo	acne2	fa
Achillea millefolium	acmi2	fu
Adiantum pedatum	adpe	fa
Agropyron cristatum	agcr	fa
Agropyron repens	agre	fw
Agropyron smithii	agsm	fu
Agropyron trachycaulum	agtr	fu
Agrostis exarata	agex	fw
Agrostis spp.	agros	fa
Agrostis stolonifera	agst2	fa
Algae	algae	ob
Alisma plantago-aquatica	alpl	ob
Alopecurus geniculatus	alge2	ob
Amaranthus retroflexus	amre	fu
Ambrosia artemisiifolia	amar2	ud
Ambrosia psilostachya	amps	fa
Ambrosia trifida	amtr	fw
Amorpha canescens	amca6	up
Andropogon scoparius ^a	ansc2	fu
Antennaria neglecta	anne	fu
Apocynum cannabinum	apca	fa
Apocynum sibericum	apsi	fa
Artemisia campestris	arcal2	fu
Artemisia cana	arcal3	fu
Asclepias incarnata	asin	ob
Asclepias speciosa	assp	fu
Asclepias spp.	ascle	fu
Aster ericoides	aser3	fu
Aster spp.	aster	fa
Bidens frondosa	bifr	fw
Bromus inermis	brin2	fu
Bromus japonicus	brja	fu
Bromus tectorum	brte	fu
Calamagrostis inexpansa	cain	fw
Carex alopecoidea	caal8	fw
Carex arctata	caar3	fw
Carex atherodes	caat2	ob
Carex aurea	caau	fw
Carex haydenii	caha7	ob
Carex interior	cain11	ob
Carex laevivaginata	calal4	ob
Carex lanuginosa	cala30	ob
Carex lasiocarpa	calal6	ob
Carex nebraskensis	cane2	ob
Carex scoparia	cascl1	fw
Carex spp.	carex	fw
Carex straminea	cast6	ob
Carex stricta	cast8	ob
Carex suberecta	casu5	ob
Carex torreyi	cato3	fw

Carex vulpinoidea	cavu2	ob
Cerastium vulgatum	cevu	fu
Chara vulgaris	chvu	ob
Chenopodium album	chal7	fa
Chenopodium hybridum	chhy	fu
Chenopodium rubrum	chru	ob
Chenopodium spp.	cheno	fu
Cicuta bulbifera	cibu	ob
Cicuta maculata	cima2	ob
Cirsium muticum	cimu	fw
Cirsium spp.	cirsi	fu
Cirsium undulatum	ciun	fu
Cirsium vulgare	civu	fu
Commelina spp.	comme	fa
Compositae	compos	nc
Conyza canadensis	coca5	fu
Coreopsis tinctoria	coti3	fa
Cornus drummondii	codr	fa
Cruciferaeae	crucif	up
Cyperaceae	cypera	nc
Cyperus spp.	cyper	fa
Dalea enneandra	daen	fw
Decodon verticillata	deve	ob
Dictylis spicata	disp	fw
Draba auricularia	drau	fa
Drepanocladus	drepa	ob
Eleocharis palustris	elpa3	ob
Eleocharis spp.	eleoc	fw
Elymus canadensis	elca4	fu
Elymus spp.	elymu	fu
Equisetum fluviatile	eqfl	ob
Equisetum laevigatum	eqla	fw
Equisetum palustre	eqpa	fw
Eragrostis spp.	eragr	fu
Erigeron flagellaris	erfl	fa
Erigeron philadelphicus	erph	fa
Erigeron strigosus	erst3	fa
Eulalia viminea	euvi	fa
Fabaceae	fabace	nc
Galium aparine	gaap2	fu
Galium obtusum	gaob	fw
Galium spp.	galiu	fu
Galium trifidum	gatr2	ob
Glycyrrhiza lepidota	glle3	fu
Gramineae	gramin	nc
Helianthus annuus	hean3	fa
Helianthus maximiliani	hema2	up
Helianthus rigida	heri2	up
Helianthus spp.	helia	up
Hordeum jubatum	hoju	fw
Hypericum canadense	hyca7	fw
Hypoxis hirsuta	hyhi2	fw
Impatiens capensis	imca	fw
Ipomoea leptophylla	iple	fu

Ipomoea spp.	ipomo	fu
Juncus balticus	juba	ob
Juncus inflexus	juin	fw
Juncus spp.	juncu	fw
Juncus tenuis	jute	fa
Juniperus virigiana	juvi	fu
Kochia scoparia	kosc	ud
Koelaria pyramidalata	kopy	up
Lactuca canadensis	laca	ud
Lactuca serriola	lase	fd
Lactuca spp.	lactu	fa
Lathyrus polymorphus	lapo2	fa
Lemna minor	lemi3	ob
Lemna trifida	letr	ob
Lepidium latifolium	lela2	fw
Lotus pershianus	lopu3	fu
Lygodesmia juncea	lyju	up
Lysimachia ciliata	lyci	fw
Lysimachia hybrida	lyhy	ob
Melilotus alba	meal2	ud
Melilotus spp.	melil	fu
Mentha arvensis	mear4	fw
Mentzella decapetalla	mede2	up
Oenothera biennis	oebi	fu
Oenothera nuttallii	oenu	fu
Oenothera spp.	oenot	fu
Ophioglossum vulgatum	opvu	fw
Opuntia imbricata	opim	up
Oxalis corniculata	oxco	fu
Panicum dichotomiflorum	padi	fa
Panicum dichotomum	padi2	fu
Panicum scribnerinum	pasc5	fu
Panicum virgatum	pavi2	fa
Parietaria pensylvanica	pape5	fa
Phalaris arundinacea	phar3	fw
Phleum pratense	phpr3	fu
Phragmites communis	phco	fw
Physalis angulata	phan5	fu
Physalis heterophylla	phhe5	fu
Plantago eriopoda	pler	fa
Plantago patagonica	plpa2	up
Poa alsodes	poal3	fw
Poa compressa	poco	fu
Poa nemoralis	pone	fa
Poa pratensis	popr	fu
Poa spp.	poa	fu
Polygonum amphibium	poam8	ob
Polygonum hydropiper	pohy	ob
Polygonum hydropiperoides	pohy2	ob
Polygonum lapathifolium	pola4	ob
Polygonum pensylvanicum	pope2	fw
Polygonum spp.	polyg	nc
Populus deltoides	pode3	fd
Potentilla paradoxa	popal5	fa

Potentilla spp.	poten	fu
Psoralea argophylla	psar2	fu
Ranunculaceae	ranunc	fu
Ratibida columnifera	raco3	up
Riccia fluitans	rifl	ob
Rorippa sinuata	rosi	fw
Rosa spp.	rosa	fu
Rudbeckia hirta	ruhi2	fu
Rumex acetosella	ruac3	fa
Rumex britannica	rubr	ob
Rumex crispus	rucr	wd
Rumex spp.	rumex	fa
Rumex verticillata	ruve3	fw
Sagittaria spp.	sagit	ob
Salix exigua	saex	ob
Salix nigra	sani	ob
Salsola kali	saka	ud
Schizachyrium scoparium ^a	scsc	ud
Scirpus acutus	scac	ob
Scirpus americanus	scam2	ob
Scirpus fluviatilis	scfl	ob
Scirpus robustus	scro	ob
Scirpus spp.	scirp	fw
Scirpus torreyii	scto	ob
Scutellaria galericulata	scga	ob
Silene antirrhina	sian2	fu
Sisyrinchium angustifolium	sian3	fa
Smilacina stellata	smst	fa
Solanum nigrum	soni	fu
Solanum spp.	solan	fu
Solidago canadensis	soca6	fu
Solidago gigantea	sogi	fw
Solidago rigida	sori	fu
Solidago spp.	solid	fu
Sorghastrum nutans	sonu2	fu
Sparganium chlorocarpum	spch	ob
Sparganium eurycarpum	speu	ob
Spartina pectinata	sppe	fw
Spirodela polyrhiza	sppo	ob
Stipa comata	stco4	up
Stipa spartea	stsp2	up
Stipa viridula	stvi4	up
Strophostyles leiosperma	stle6	fu
Symphoricarpos occidentalis	syoc	fu
Talinum teretifolium	tate	fu
Taraxacum officinale	taof	fu
Teucrium canadense	teca3	fw
Toxicodendron radicans	tora2	fu
Tragopogon dubius	trdu	up
Trifolium pratense	trpr2	fu
Trifolium procumbens	trpr3	fu
Triglochin maritimum	trma4	ob
Triodanis perfoliata	trpe4	fa
Typha angustifolia	tyan	ob

Typha latifolia	tyla	ob
Unknown Forb	uf	nc
Urtica dioecia	urdi	fw
Utricularia macrorhiza	utma	ob
Vernonia baldwinii	veba	fu
Vernonia fasciculata	vefa2	fa
Vernonia spp.	verno	fa
Veronica americana	veam2	ob
Veronica spp.	veron	fa
Viola spp.	viola	fu
Xanthium strumarium	xast	fd
Yucca spp.	yucca	fu

^a Andropogon scoparius and Schizachyrium scoparium are the same species (the latter is correct).

APPENDIX C

FREQUENCIES OF OCCURRENCE OF SPECIES FOUND ON
SOIL SERIES WITHIN EACH STUDY AREA

Appendix C-1. Frequency of occurrence of species found on 40 replications of Massie soil, Rainwater Basin.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
elpa3	358	18.8	358	18.8
poam8	327	17.2	685	36.0
algae	300	15.8	985	51.7
pavi2	265	13.9	1250	65.7
phar3	153	8.0	1403	73.7
spch	82	4.3	1485	78.0
arcal3	64	3.4	1549	81.4
cala30	55	2.9	1604	84.2
tyla	52	2.7	1656	87.0
teca3	46	2.4	1702	89.4
pola4	44	2.3	1746	91.7
casu5	43	2.3	1789	94.0
brin2	31	1.6	1820	95.6
sagit	16	0.8	1836	96.4
juba	15	0.8	1851	97.2
uf	14	0.7	1865	98.0
cibu	13	0.7	1878	98.6
hoju	7	0.4	1885	99.0
vefa2	7	0.4	1892	99.4
apsi	3	0.2	1895	99.5
rubr	3	0.2	1898	99.7
amar2	2	0.1	1900	99.8
oxco	2	0.1	1902	99.9
drepa	1	0.1	1903	99.9
rucr	1	0.1	1904	100.0

Appendix C-2. Frequency of occurrence of species found on 40 replications of Fillmore soil, Rainwater Basin.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
amar2	354	15.7	354	15.7
phar3	342	15.1	696	30.8
agst2	276	12.2	972	43.0
elpa3	204	9.0	1176	52.1
pone	146	6.5	1322	58.5
poam8	139	6.2	1461	64.7
alge2	102	4.5	1563	69.2
cala30	90	4.0	1653	73.2
meal2	90	4.0	1743	77.2
coca5	73	3.2	1816	80.4
hoju	59	2.6	1875	83.0
rucr	50	2.2	1925	85.3
mear4	46	2.0	1971	87.3
cane2	29	1.3	2000	88.6
verno	25	1.1	2025	89.7
pohy	24	1.1	2049	90.7
compos	23	1.0	2072	91.8
arcal3	21	0.9	2093	92.7
cibu	21	0.9	2114	93.6
lase	21	0.9	2135	94.6
gramin	19	0.8	2154	95.4
brin2	14	0.6	2168	96.0
amtr	10	0.4	2178	96.5
uf	9	0.4	2187	96.9
acmi2	7	0.3	2194	97.2
lela2	7	0.3	2201	97.5
lopu3	6	0.3	2207	97.7
oxco	6	0.3	2213	98.0
teca3	6	0.3	2219	98.3
ciun	5	0.2	2224	98.5
pola4	5	0.2	2229	98.7
veam2	5	0.2	2234	98.9
apsi	4	0.2	2238	99.1
cimu	4	0.2	2242	99.3
gaap2	4	0.2	2246	99.5
asin	3	0.1	2249	99.6
cirsi	2	0.1	2251	99.7
poten	2	0.1	2253	99.8
solid	2	0.1	2255	99.9
calal6	1	0.0	2256	99.9
carex	1	0.0	2257	100.0
trpe4	1	0.0	2258	100.0

Appendix C-3. Frequency of occurrence of species found on 40 replications of Scott soil, Rainwater Basin.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
brin2	338	16.5	338	16.5
amar2	324	15.8	662	32.3
gramin	320	15.6	982	48.0
agst2	188	9.2	1170	57.2
hoju	117	5.7	1287	62.9
pone	106	5.2	1393	68.1
poam8	82	4.0	1475	72.1
elpa3	77	3.8	1552	75.8
phar3	53	2.6	1605	78.4
lopu3	51	2.5	1656	80.9
pavi2	48	2.3	1704	83.2
lase	45	2.2	1749	85.4
cala30	44	2.1	1793	87.6
coca5	44	2.1	1837	89.7
uf	44	2.1	1881	91.9
oxco	19	0.9	1900	92.8
compos	18	0.9	1918	93.7
pola4	18	0.9	1936	94.6
cimu	15	0.7	1951	95.3
solid	13	0.6	1964	95.9
ciun	10	0.5	1974	96.4
arcal3	9	0.4	1983	96.9
apsi	8	0.4	1991	97.3
cibu	8	0.4	1999	97.7
teca3	7	0.3	2006	98.0
gaap2	6	0.3	2012	98.3
lela2	5	0.2	2017	98.5
rucr	5	0.2	2022	98.8
asin	3	0.1	2025	98.9
carex	3	0.1	2028	99.1
elac	3	0.1	2031	99.2
amre	2	0.1	2033	99.3
cirsi	2	0.1	2035	99.4
rubr	2	0.1	2037	99.5
apca	1	0.0	2038	99.6
aster	1	0.0	2039	99.6
caau3	1	0.0	2040	99.7
cascl1	1	0.0	2041	99.7
cavu2	1	0.0	2042	99.8
cevu	1	0.0	2043	99.8
drau	1	0.0	2044	99.9
juin	1	0.0	2045	99.9
sian2	1	0.0	2046	100.0
trpe4	1	0.0	2047	100.0

Appendix C-4. Frequency of occurrence of species found on 38 replications of Butler soil, Rainwater Basin.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
brin2	510	28.2	510	28.2
poam8	212	11.7	722	39.9
pone	205	11.3	927	51.3
pavi2	192	10.6	1119	61.9
amar2	115	6.4	1234	68.3
gramin	89	4.9	1323	73.2
lase	84	4.6	1407	77.8
gaap2	72	4.0	1479	81.8
agst2	52	2.9	1531	84.7
cimu	36	2.0	1567	86.7
ciun	31	1.7	1598	88.4
cala30	30	1.7	1628	90.0
mear4	19	1.1	1647	91.1
cirsi	16	0.9	1663	92.0
juin	14	0.8	1677	92.8
ipomo	13	0.7	1690	93.5
asin	12	0.7	1702	94.1
compos	11	0.6	1713	94.7
oxco	11	0.6	1724	95.4
rucr	11	0.6	1735	96.0
uf	10	0.6	1745	96.5
hoju	9	0.5	1754	97.0
trpe4	8	0.4	1762	97.5
calal4	6	0.3	1768	97.8
erst3	6	0.3	1774	98.1
phar3	6	0.3	1780	98.5
coca5	5	0.3	1785	98.7
acmi2	4	0.2	1789	98.9
apca	3	0.2	1792	99.1
apsi	3	0.2	1795	99.3
cibu	3	0.2	1798	99.4
lopu3	3	0.2	1801	99.6
solid	3	0.2	1804	99.8
teca3	2	0.1	1806	99.9
cevu	1	0.1	1807	99.9
pape5	1	0.1	1808	100.0

Appendix C-5. Frequency of occurrence of species found on 40 replications of Marlake soil, Rock County.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
utma	360	17.8	360	17.8
lemi3	260	12.9	620	30.7
letr	181	9.0	801	39.7
scfl	143	7.1	944	46.7
elpa3	130	6.4	1074	53.2
cavu2	121	6.0	1195	59.2
tyla	120	5.9	1315	65.1
caat2	103	5.1	1418	70.2
sagit	91	4.5	1509	74.7
cala30	84	4.2	1593	78.9
cain	61	3.0	1654	81.9
caal8	58	2.9	1712	84.8
poam8	56	2.8	1768	87.5
poa	50	2.5	1818	90.0
ascle	35	1.7	1853	91.7
gramin	33	1.6	1886	93.4
sppo	33	1.6	1919	95.0
tyan	16	0.8	1935	95.8
calal4	15	0.7	1950	96.5
pohy2	15	0.7	1965	97.3
carex	13	0.6	1978	97.9
caca4	12	0.6	1990	98.5
phar3	8	0.4	1998	98.9
speu	8	0.4	2006	99.3
deve	4	0.2	2010	99.5
coca5	2	0.1	2012	99.6
rumex	2	0.1	2014	99.7
cima2	1	0.0	2015	99.8
eleoc	1	0.0	2016	99.8
galiu	1	0.0	2017	99.9
ranunc	1	0.0	2018	99.9
rucr	1	0.0	2019	100.0
uf	1	0.0	2020	100.0

Appendix C-6. Frequency of occurrence of species on 40 replications of Loup soil, Rock County.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
cast6	350	15.4	350	15.4
elpa3	331	14.5	681	29.9
trpr2	249	10.9	930	40.9
agst2	176	7.7	1106	48.6
hoju	155	6.8	1261	55.4
cala30	104	4.6	1365	60.0
cavu2	97	4.3	1462	64.3
teca3	94	4.1	1556	68.4
poa	81	3.6	1637	72.0
scam2	63	2.8	1700	74.7
poco	48	2.1	1748	76.8
amar2	42	1.8	1790	78.7
caal8	42	1.8	1832	80.5
phpr3	39	1.7	1871	82.2
carex	32	1.4	1903	83.6
popr	31	1.4	1934	85.0
phar3	28	1.2	1962	86.2
cascl1	25	1.1	1987	87.3
poam8	24	1.1	2011	88.4
cainl1	21	0.9	2032	89.3
gramin	19	0.8	2051	90.2
juin	19	0.8	2070	91.0
plpa2	18	0.8	2088	91.8
brin2	16	0.7	2104	92.5
lase	16	0.7	2120	93.2
compos	14	0.6	2134	93.8
drepa	13	0.6	2147	94.4
pohy2	12	0.5	2159	94.9
trpr3	11	0.5	2170	95.4
agex	10	0.4	2180	95.8
apsi	9	0.4	2189	96.2
uf	9	0.4	2198	96.6
solid	8	0.4	2206	97.0
caha7	6	0.3	2212	97.2
cato3	6	0.3	2218	97.5
gaob	5	0.2	2223	97.7
rumex	5	0.2	2228	97.9
juba	4	0.2	2232	98.1
mear4	4	0.2	2236	98.3
padi2	4	0.2	2240	98.5
rucr	4	0.2	2244	98.6
cast8	3	0.1	2247	98.8
eleoc	3	0.1	2250	98.9
eqfl	3	0.1	2253	99.0
meal2	3	0.1	2256	99.2
veron	3	0.1	2259	99.3

acmi2	2	0.1	2261	99.4
ruve3	2	0.1	2263	99.5
soca6	2	0.1	2265	99.6
hyca7	1	0.0	2266	99.6
juncu	1	0.0	2267	99.6
lactu	1	0.0	2268	99.7
lemi3	1	0.0	2269	99.7
oxco	1	0.0	2270	99.8
phan5	1	0.0	2271	99.8
pola4	1	0.0	2272	99.9
pope2	1	0.0	2273	99.9
sppo	1	0.0	2274	100.0
veba	1	0.0	2275	100.0

Appendix C-7. Frequency of occurrence of species found on 40 replications of Tryon soil, Rock County.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
cast6	387	16.7	387	16.7
eragr	341	14.7	728	31.4
trpr2	148	6.4	876	37.8
agex	119	5.1	995	42.9
brja	117	5.0	1112	48.0
elpa3	111	4.8	1223	52.8
phpr3	110	4.7	1333	57.5
cala30	108	4.7	1441	62.2
poa	63	2.7	1504	64.9
caal8	52	2.2	1556	67.1
agst2	50	2.2	1606	69.3
agros	48	2.1	1654	71.4
phar3	48	2.1	1702	73.4
gramin	45	1.9	1747	75.4
caha7	44	1.9	1791	77.3
hoju	42	1.8	1833	79.1
juin	42	1.8	1875	80.9
carex	39	1.7	1914	82.6
teca3	38	1.6	1952	84.2
lase	24	1.0	1976	85.2
eqfl	21	0.9	1997	86.2
acmi2	19	0.8	2016	87.0
brte	19	0.8	2035	87.8
cato3	19	0.8	2054	88.6
padi2	18	0.8	2072	89.4
uf	16	0.7	2088	90.1
assp	15	0.6	2103	90.7
poam8	15	0.6	2118	91.4
pohy2	15	0.6	2133	92.0
juncu	14	0.6	2147	92.6
oxco	12	0.5	2159	93.1
plpa2	12	0.5	2171	93.7
juba	11	0.5	2182	94.1
sian2	10	0.4	2192	94.6
solid	9	0.4	2201	95.0
drepa	8	0.3	2209	95.3
cavu2	7	0.3	2216	95.6
eleoc	7	0.3	2223	95.9
ipomo	7	0.3	2230	96.2
meal2	7	0.3	2237	96.5
scfl	7	0.3	2244	96.8
amar2	6	0.3	2250	97.1
cate3	6	0.3	2256	97.3
phan5	6	0.3	2262	97.6
rucr	6	0.3	2268	97.8
viola	6	0.3	2274	98.1

scam2	5	0.2	2279	98.3
eqpa	4	0.2	2283	98.5
lemi3	4	0.2	2287	98.7
apca	3	0.1	2290	98.8
galiu	3	0.1	2293	98.9
trpr3	3	0.1	2296	99.1
apsi	2	0.1	2298	99.1
ascle	2	0.1	2300	99.2
eqla	2	0.1	2302	99.3
pola4	2	0.1	2304	99.4
sagit	2	0.1	2306	99.5
sppe	2	0.1	2308	99.6
coca5	1	0.0	2309	99.6
cypera	1	0.0	2310	99.7
elco2	1	0.0	2311	99.7
erph	1	0.0	2312	99.7
mear4	1	0.0	2313	99.8
opvu	1	0.0	2314	99.8
pasc5	1	0.0	2315	99.9
phco	1	0.0	2316	99.9
rosi	1	0.0	2317	100.0
trdu	1	0.0	2318	100.0

Appendix C-8. Frequency of occurrence of species found on 40 replications of Marlake soil, Valentine National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
cala30	295	16.3	295	16.3
utma	266	14.7	561	30.9
elpa3	228	12.6	789	43.5
caal8	180	9.9	969	53.4
phar3	180	9.9	1149	63.3
drepa	155	8.5	1304	71.8
caat2	90	5.0	1394	76.8
sagit	88	4.8	1482	81.7
deve	70	3.9	1552	85.5
poam8	47	2.6	1599	88.1
tyla	37	2.0	1636	90.1
cast6	23	1.3	1659	91.4
carex	22	1.2	1681	92.6
caha7	19	1.0	1700	93.7
lemi3	18	1.0	1718	94.7
agst2	16	0.9	1734	95.5
sppo	15	0.8	1749	96.4
scga	11	0.6	1760	97.0
gaob	8	0.4	1768	97.4
sppe	8	0.4	1776	97.9
juba	7	0.4	1783	98.2
rifl	5	0.3	1788	98.5
rumex	4	0.2	1792	98.7
cain11	3	0.2	1795	98.9
letr	3	0.2	1798	99.1
speu	3	0.2	1801	99.2
veron	3	0.2	1804	99.4
cavu2	2	0.1	1806	99.5
cima2	2	0.1	1808	99.6
mear4	2	0.1	1810	99.7
adpe	1	0.1	1811	99.8
asin	1	0.1	1812	99.8
polyg	1	0.1	1813	99.9
spga	1	0.1	1814	99.9
uf	1	0.1	1815	100.0

Appendix C-9. Frequency of occurrence of species found on 40 replications of Tryon soil, Valentine National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
agst2	289	15.3	289	15.3
phpr3	216	11.4	505	26.7
cala30	202	10.7	707	37.3
popr	160	8.4	867	45.8
trpr2	127	6.7	994	52.5
phar3	123	6.5	1117	59.0
juba	89	4.7	1206	63.7
cast6	75	4.0	1281	67.6
elpa3	75	4.0	1356	71.6
acmi2	71	3.7	1427	75.3
trpr3	51	2.7	1478	78.0
poal3	42	2.2	1520	80.3
caal8	39	2.1	1559	82.3
pasc5	32	1.7	1591	84.0
carex	30	1.6	1621	85.6
juin	27	1.4	1648	87.0
eqfl	25	1.3	1673	88.3
cascl1	24	1.3	1697	89.6
drepa	20	1.1	1717	90.7
cainl1	17	0.9	1734	91.6
sppe	15	0.8	1749	92.3
eleoc	13	0.7	1762	93.0
cavu2	12	0.6	1774	93.7
brin2	10	0.5	1784	94.2
cato3	9	0.5	1793	94.7
erst3	6	0.3	1799	95.0
eula	6	0.3	1805	95.3
oxco	6	0.3	1811	95.6
sogi	6	0.3	1817	95.9
amar2	5	0.3	1822	96.2
arcal3	5	0.3	1827	96.5
ascle	5	0.3	1832	96.7
caha7	5	0.3	1837	97.0
laca	5	0.3	1842	97.3
lase	5	0.3	1847	97.5
anne	4	0.2	1851	97.7
daen	4	0.2	1855	97.9
meal2	4	0.2	1859	98.2
popal5	4	0.2	1863	98.4
ruac3	4	0.2	1867	98.6
heri2	3	0.2	1870	98.7
hyhi2	3	0.2	1873	98.9
pavi2	3	0.2	1876	99.0
taof	3	0.2	1879	99.2
agtr	2	0.1	1881	99.3
soca6	2	0.1	1883	99.4

uf	2	0.1	1885	99.5
viola	2	0.1	1887	99.6
aser3	1	0.1	1888	99.7
juncu	1	0.1	1889	99.7
lactu	1	0.1	1890	99.8
lopu3	1	0.1	1891	99.8
plpa2	1	0.1	1892	99.9
ruhi2	1	0.1	1893	99.9
teca3	1	0.1	1894	100.0

Appendix C-10. Frequency of occurrence of species found on 30 replications of Els soil, Valentine National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
popr	203	14.2	203	14.2
agst2	178	12.4	381	26.6
acmi2	175	12.2	556	38.8
pavi2	140	9.8	696	48.5
trpr2	112	7.8	808	56.3
pasc5	105	7.3	913	63.7
phpr3	91	6.3	1004	70.0
arcal3	71	5.0	1075	75.0
cala30	67	4.7	1142	79.6
eqfl	56	3.9	1198	83.5
lapo2	31	2.2	1229	85.7
phar3	30	2.1	1259	87.8
juba	23	1.6	1282	89.4
elpa3	22	1.5	1304	90.9
amar2	13	0.9	1317	91.8
juin	12	0.8	1329	92.7
trdu	12	0.8	1341	93.5
carex	10	0.7	1351	94.2
trpr3	10	0.7	1361	94.9
uf	9	0.6	1370	95.5
kopy	8	0.6	1378	96.1
cast6	6	0.4	1384	96.5
cato3	5	0.3	1389	96.9
ecan2	4	0.3	1393	97.1
oxco	4	0.3	1397	97.4
raco3	4	0.3	1401	97.7
amca6	3	0.2	1404	97.9
anne	3	0.2	1407	98.1
erst3	3	0.2	1410	98.3
heri2	3	0.2	1413	98.5
psar2	3	0.2	1416	98.7
fabace	2	0.1	1418	98.9
laca	2	0.1	1420	99.0
phhe5	2	0.1	1422	99.2
sian2	2	0.1	1424	99.3
sogi	2	0.1	1426	99.4
ascle	1	0.1	1427	99.5
brja	1	0.1	1428	99.6
hyhi2	1	0.1	1429	99.7
lase	1	0.1	1430	99.7
popal5	1	0.1	1431	99.8
ruhi2	1	0.1	1432	99.9
rumex	1	0.1	1433	99.9
viola	1	0.1	1434	100.0

Appendix C -11. Frequency of occurrence of species found on 10 replications of Ipage soil, Valentine National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
popr	107	18.9	107	18.9
trpr2	72	12.7	179	31.7
acmi2	69	12.2	248	43.9
cain11	36	6.4	284	50.3
pasc5	36	6.4	320	56.6
pavi2	28	5.0	348	61.6
psar2	28	5.0	376	66.5
agst2	26	4.6	402	71.2
lapo2	25	4.4	427	75.6
phpr3	22	3.9	449	79.5
arcal3	19	3.4	468	82.8
eqfl	13	2.3	481	85.1
trdu	12	2.1	493	87.3
gramin	10	1.8	503	89.0
oxco	9	1.6	512	90.6
trpr3	9	1.6	521	92.2
civu	8	1.4	529	93.6
juba	6	1.1	535	94.7
agcr	4	0.7	539	95.4
amps	3	0.5	542	95.9
anne	3	0.5	545	96.5
cascl1	3	0.5	548	97.0
erst3	3	0.5	551	97.5
lase	3	0.5	554	98.1
carex	2	0.4	556	98.4
phar3	2	0.4	558	98.8
taof	2	0.4	560	99.1
uf	2	0.4	562	99.5
cala30	1	0.2	563	99.6
cirsi	1	0.2	564	99.8
juin	1	0.2	565	100.0

Appendix C-12. Frequency of occurrence of species found on 109 replications of Marlake soil, Crescent Lake National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
algae	448	13.6	448	13.6
scto	390	11.8	838	25.4
poam8	328	10.0	1166	35.4
tyla	240	7.3	1406	42.7
phar3	222	6.7	1628	49.4
uf	215	6.5	1843	55.9
carex	201	6.1	2044	62.0
scac	194	5.9	2238	67.9
imca	105	3.2	2343	71.1
mear4	105	3.2	2448	74.3
drepa	69	2.1	2517	76.4
hoju	59	1.8	2576	78.2
sppe	58	1.8	2634	79.9
caat2	50	1.5	2684	81.4
cala30	49	1.5	2733	82.9
speu	48	1.5	2781	84.4
scga	39	1.2	2820	85.6
sagit	38	1.2	2858	86.7
eleoc	35	1.1	2893	87.8
disp	29	0.9	2922	88.7
elpa3	28	0.8	2950	89.5
ascle	26	0.8	2976	90.3
cavu2	25	0.8	3001	91.0
agst2	22	0.7	3023	91.7
cast6	22	0.7	3045	92.4
deve	22	0.7	3067	93.1
chhy	21	0.6	3088	93.7
teca3	20	0.6	3108	94.3
vefa2	20	0.6	3128	94.9
urdi	19	0.6	3147	95.5
juin	15	0.5	3162	95.9
gaob	12	0.4	3174	96.3
hema2	12	0.4	3186	96.7
trma4	12	0.4	3198	97.0
scirp	11	0.3	3209	97.4
gatr2	10	0.3	3219	97.7
oebi	8	0.2	3227	97.9
sogi	7	0.2	3234	98.1
cheno	6	0.2	3240	98.3
juncu	6	0.2	3246	98.5
amar2	5	0.2	3251	98.6
amps	5	0.2	3256	98.8
losi	5	0.2	3261	98.9
rucr	4	0.1	3265	99.1
soca6	4	0.1	3269	99.2

alpl	3	0.1	3272	99.3
apsi	3	0.1	3275	99.4
elymu	3	0.1	3278	99.5
sian3	3	0.1	3281	99.5
brja	2	0.1	3283	99.6
chvu	2	0.1	3285	99.7
cirsi	2	0.1	3287	99.7
gramin	2	0.1	3289	99.8
scro	2	0.1	3291	99.8
aster	1	0.0	3292	99.9
bifr	1	0.0	3293	99.9
phpr3	1	0.0	3294	99.9
poten	1	0.0	3295	100.0
tate	1	0.0	3296	100.0

Appendix C-13. Frequency of occurrence of species found on 40 replications of Hoffland soil, Crescent Lake National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
carex	292	22.3	292	22.3
phar3	122	9.3	414	31.6
agst2	116	8.8	530	40.4
gramin	85	6.5	615	46.9
popr	69	5.3	684	52.1
agtr	65	5.0	749	57.1
hoju	64	4.9	813	62.0
cala30	55	4.2	868	66.2
poam8	46	3.5	914	69.7
brja	42	3.2	956	72.9
soca6	38	2.9	994	75.8
scto	28	2.1	1022	77.9
cain11	26	2.0	1048	79.9
ansc2	25	1.9	1073	81.8
smst	25	1.9	1098	83.7
cavu2	24	1.8	1122	85.5
juba	21	1.6	1143	87.1
sppe	21	1.6	1164	88.7
vefa2	20	1.5	1184	90.2
juin	16	1.2	1200	91.5
teca3	13	1.0	1213	92.5
civu	11	0.8	1224	93.3
cirsi	10	0.8	1234	94.1
juncu	9	0.7	1243	94.7
viola	7	0.5	1250	95.3
agre	6	0.5	1256	95.7
assp	6	0.5	1262	96.2
elpa3	6	0.5	1268	96.6
trma4	6	0.5	1274	97.1
plpa2	5	0.4	1279	97.5
mear4	4	0.3	1283	97.8
amar2	3	0.2	1286	98.0
eqfl	3	0.2	1289	98.2
jute	3	0.2	1292	98.5
lase	3	0.2	1295	98.7
meal2	2	0.2	1297	98.9
rucr	2	0.2	1299	99.0
ruhi2	2	0.2	1301	99.2
scga	2	0.2	1303	99.3
stco4	2	0.2	1305	99.5
uf	2	0.2	1307	99.6
chru	1	0.1	1308	99.7
coca5	1	0.1	1309	99.8
scirp	1	0.1	1310	99.8
tate	1	0.1	1311	99.9
trpr3	1	0.1	1312	100.0

Appendix C-14. Frequency of occurrence of species found on 40 replications of Loup soil, Crescent Lake National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
carex	160	16.4	160	16.4
poam8	153	15.7	313	32.1
phar3	110	11.3	423	43.3
vefa2	69	7.1	492	50.4
juncu	62	6.4	554	56.8
soca6	53	5.4	607	62.2
popr	41	4.2	648	66.4
pavi2	32	3.3	680	69.7
urdi	31	3.2	711	72.8
lopu3	29	3.0	740	75.8
juin	27	2.8	767	78.6
assp	23	2.4	790	80.9
caar3	22	2.3	812	83.2
civu	19	1.9	831	85.1
amps	14	1.4	845	86.6
teca3	14	1.4	859	88.0
ecsp	12	1.2	871	89.2
mear4	12	1.2	883	90.5
deve	11	1.1	894	91.6
agre	9	0.9	903	92.5
agst2	8	0.8	911	93.3
cirsi	7	0.7	918	94.1
juba	6	0.6	924	94.7
oenot	6	0.6	930	95.3
poco	6	0.6	936	95.9
uf	5	0.5	941	96.4
veba	5	0.5	946	96.9
sori	4	0.4	950	97.3
chru	3	0.3	953	97.6
cima2	3	0.3	956	98.0
gatr2	3	0.3	959	98.3
ruhi2	3	0.3	962	98.6
agsm	2	0.2	964	98.8
coca5	2	0.2	966	99.0
agtr	1	0.1	967	99.1
apca	1	0.1	968	99.2
apsi	1	0.1	969	99.3
erph	1	0.1	970	99.4
heri2	1	0.1	971	99.5
lyci	1	0.1	972	99.6
lyhy	1	0.1	973	99.7
poten	1	0.1	974	99.8
scga	1	0.1	975	99.9
trma4	1	0.1	976	100.0

Appendix C-15. Frequency of occurrence of species found on 40 replications of Tryon soil, Crescent Lake National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
phar3	164	15.7	164	15.7
agsm	154	14.7	318	30.4
trpr3	114	10.9	432	41.3
agre	110	10.5	542	51.9
popr	88	8.4	630	60.3
elca4	54	5.2	684	65.5
sonu2	48	4.6	732	70.0
agst2	35	3.3	767	73.4
carex	34	3.3	801	76.7
brin2	32	3.1	833	79.7
veba	25	2.4	858	82.1
brja	23	2.2	881	84.3
juin	18	1.7	899	86.0
lopu3	18	1.7	917	87.8
pavi2	18	1.7	935	89.5
poco	16	1.5	951	91.0
phpr3	12	1.1	963	92.2
lase	10	1.0	973	93.1
agex	9	0.9	982	94.0
hema	8	0.8	990	94.7
rucr	7	0.7	997	95.4
cain11	6	0.6	1003	96.0
coca5	6	0.6	1009	96.6
melil	6	0.6	1015	97.1
chal7	4	0.4	1019	97.5
trpr2	4	0.4	1023	97.9
ansc2	3	0.3	1026	98.2
oenot	3	0.3	1029	98.5
eqfl	2	0.2	1031	98.7
juncu	2	0.2	1033	98.9
meal2	2	0.2	1035	99.0
uf	2	0.2	1037	99.2
amps	1	0.1	1038	99.3
eleoc	1	0.1	1039	99.4
fabace	1	0.1	1040	99.5
heri2	1	0.1	1041	99.6
juba	1	0.1	1042	99.7
plpa2	1	0.1	1043	99.8
sian2	1	0.1	1044	99.9
stle6	1	0.1	1045	100.0

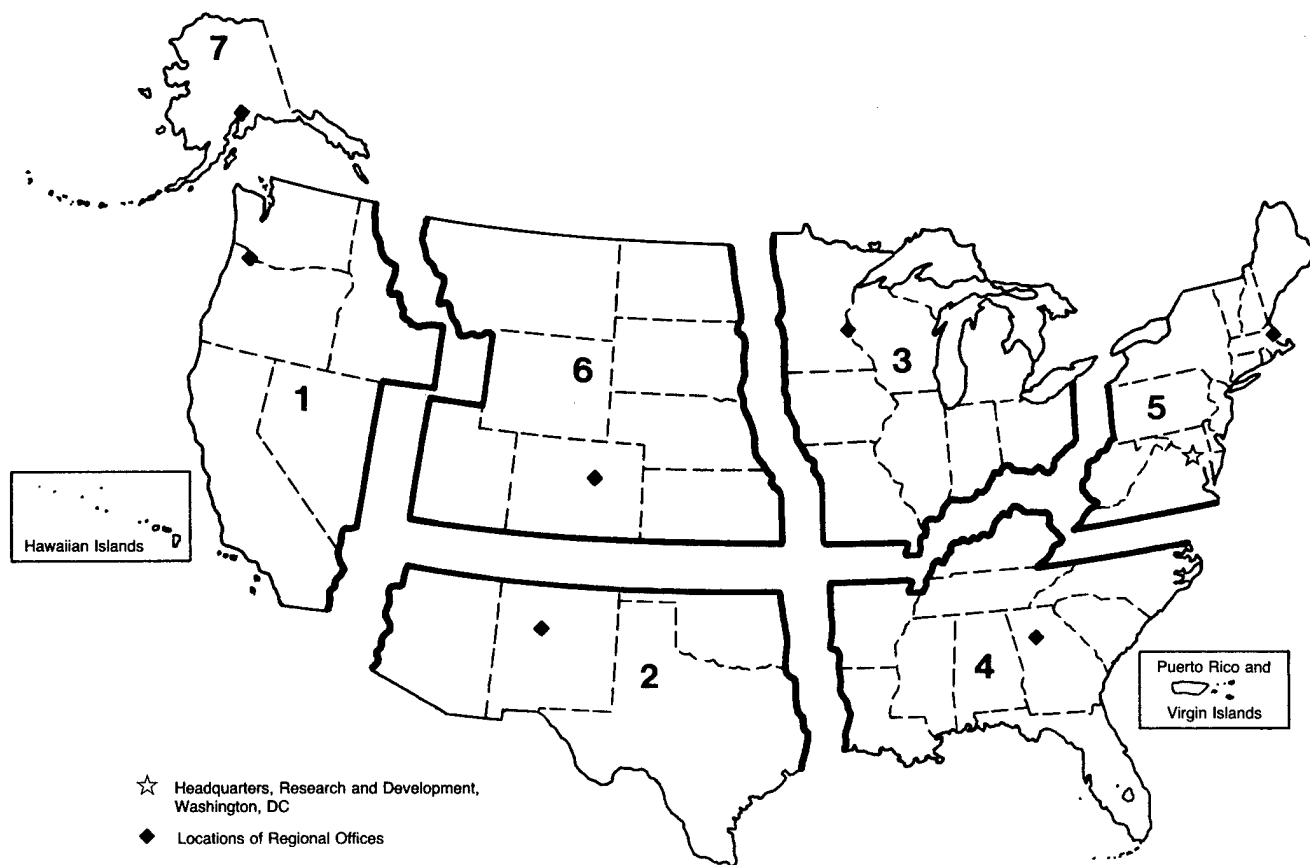
Appendix C -16. Frequency of occurrence of species found on 70 replications of Els soil, Crescent Lake National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
popr	139	9.2	139	9.2
agtr	138	9.1	277	18.3
stco4	103	6.8	380	25.1
phar3	100	6.6	480	31.7
pavi2	98	6.5	578	38.2
brja	89	5.9	667	44.1
brte	82	5.4	749	49.5
meal2	67	4.4	816	53.9
ansc2	66	4.4	882	58.3
carex	66	4.4	948	62.6
elca4	61	4.0	1009	66.6
tora2	58	3.8	1067	70.5
amar2	56	3.7	1123	74.2
arcal3	48	3.2	1171	77.3
uf	43	2.8	1214	80.2
solan	40	2.6	1254	82.8
mede2	36	2.4	1290	85.2
poam8	17	1.1	1307	86.3
coca5	16	1.1	1323	87.4
cain11	15	1.0	1338	88.4
gramin	15	1.0	1353	89.4
oenot	14	0.9	1367	90.3
juba	13	0.9	1380	91.1
plpa2	13	0.9	1393	92.0
agsm	8	0.5	1401	92.5
iple	8	0.5	1409	93.1
agre	7	0.5	1416	93.5
arcal2	7	0.5	1423	94.0
soca6	7	0.5	1430	94.5
assp	6	0.4	1436	94.8
lase	6	0.4	1442	95.2
phhe5	6	0.4	1448	95.6
apca	5	0.3	1453	96.0
eqfl	5	0.3	1458	96.3
juncu	5	0.3	1463	96.6
agst2	4	0.3	1467	96.9
disp	4	0.3	1471	97.2
lapo2	4	0.3	1475	97.4
xast	4	0.3	1479	97.7
cheno	3	0.2	1482	97.9
crucif	3	0.2	1485	98.1
helia	3	0.2	1488	98.3
hoju	3	0.2	1491	98.5
pler	3	0.2	1494	98.7
stsp2	3	0.2	1497	98.9
vefa2	3	0.2	1500	99.1

Appendix C-17. Frequency of occurrence of species found on 40 replications of Valentine soil, Crescent Lake National Wildlife Refuge.

SP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
stvi4	143	24.0	143	24.0
ansc2	65	10.9	208	34.9
brja	64	10.7	272	45.6
popr	61	10.2	333	55.9
arcal2	50	8.4	383	64.3
stco4	47	7.9	430	72.1
arcal3	41	6.9	471	79.0
yucca	25	4.2	496	83.2
soni	20	3.4	516	86.6
agtr	14	2.3	530	88.9
agre	13	2.2	543	91.1
comme	11	1.8	554	93.0
mede2	7	1.2	561	94.1
assp	5	0.8	566	95.0
scsc	5	0.8	571	95.8
amar2	4	0.7	575	96.5
lyju	4	0.7	579	97.1
coti3	3	0.5	582	97.7
cyper	2	0.3	584	98.0
kosc	2	0.3	586	98.3
oenot	2	0.3	588	98.7
uf	2	0.3	590	99.0
cheno	1	0.2	591	99.2
eqfl	1	0.2	592	99.3
helia	1	0.2	593	99.5
heri2	1	0.2	594	99.7
opim	1	0.2	595	99.8
polyg	1	0.2	596	100.0

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